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International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01F 27/34 — A1

(11) International Publication Number: WO 98/34248

(43) International Publication Date: 6 August 1998 (06.08.98)

(21) International Application Number: PCT/SE98/00178

(22) International Filing Date: 2 February 1998 (02.02.98)

(30) Priority Data:

9700340-4	3 February 1997 (03.02.97)	SE
9704436-6	28 November 1997 (28.11.97)	SE

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(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, ES, FI, FI (Utility model), GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

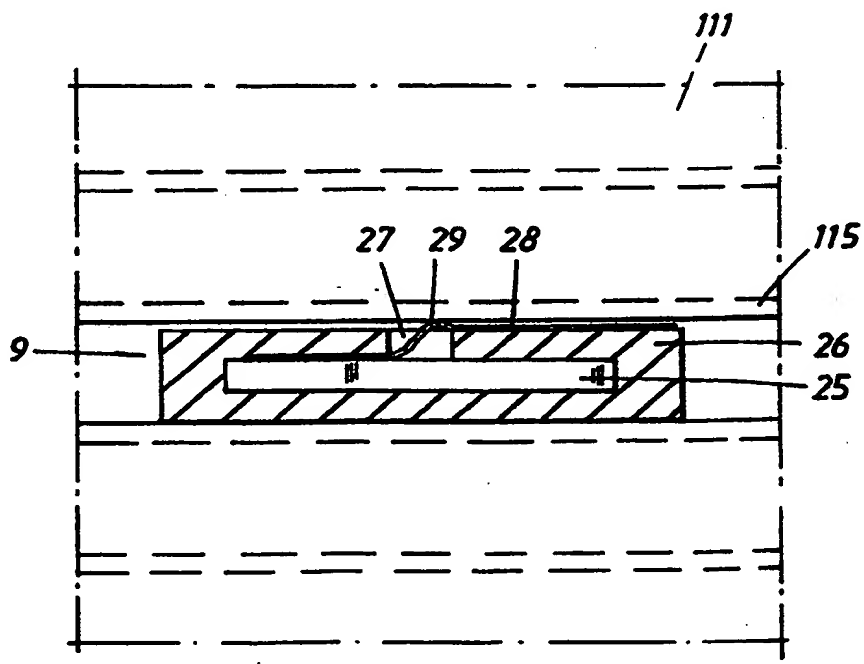
Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.
In English translation (filed in Swedish).

(54) Title: A WINDING PROVIDED WITH SPACERS

(57) Abstract

Winding (3) formed as a coil with winding turns situated radially one on top of the other, wherein the winding (3) consists of high-voltage cable (111) provided with an outer semi-conducting layer (115), and wherein the winding (3) is provided with spacers (8, 9) disposed axially between each turn of the winding to separate the winding, said spacers being provided with an earthing member (11, 17, 18, 28) connected to the semi-conducting layer (115) of the high-voltage cable (111).



A WINDING PROVIDED WITH SPACERS

TECHNICAL FIELD:

The present invention relates to a winding in an air-cooled, cable-wound power transformer or a winding in a reactor, said winding being provided with spacers between the cable windings in order to enable air-cooling and earthing in a mechanically coherent winding structure.

BACKGROUND ART:

Modern power transformers are usually oil-cooled. The transformers are provided with a core, consisting of a number of core legs joined by yokes, and with windings forming coils (primary, secondary, control), which are immersed in a closed container filled with oil. Heat generated in coils and core is removed by the oil circulating internally through coils and core, which transfers the heat to the surrounding air via the walls of the container. The oil circulation may either be forced, the oil being pumped around, or it may be natural, produced by temperature differences in the oil. The circulating oil is cooled externally by arrangements for air-cooling or water-cooling. External air-cooling may be either forced and/or be effected through natural convection. Besides its role as conveyor of heat, the oil also has an insulating function in oil-cooled transformers for high voltage.

Dry transformers are usually air-cooled. They are usually cooled through natural convection since today's dry transformers are used at low power loads. The present technology relates to axial cooling ducts produced by means of a pleated winding as described in GB 1,147,049, axial ducts for cooling windings embedded in casting resin as described in EP 83107410.9, and the use of cross-current fans at peak loads as described in SE 7303919-0.

Since it is possible by using a winding of high-voltage cable, to construct a dry transformer having more power than existing dry power transformers, these new power transformers require more efficient cooling. Forced convection is therefore necessary to satisfy the cooling requirement in all

the windings. A short transport route for the h at to th coolant is important and also that it is efficiently transferred to the coolant. It is therefore important that all windings are in direct contact with sufficient quantities of coolant.

Conventional power transformers are also provided with special rings to ensure the stability of the windings against short-circuiting forces. The windings are also assembled on the core as a unit. Thereafter a series of pressure plates are mounted and clamped against a barrier cylinder. The entire assembly is mounted aligned on a lower spacer ring. A compression ring is located between the core yoke and windings in order to pre-stress the windings. The short-circuiting forces must therefore be taken up by the yoke of the iron core itself and the clamps holding the lamination together.

If the winding is to be used in a reactor to compensate reactive power, the winding coil may be made without an iron core. In this case the winding consists only of a coil.

According to US 5 036 165 a conductor is known having insulation provided with an inner and an outer layer of semiconducting pyrolized glassfiber. It is also known to provide conductors in a dynamo-electric machine with such insulation, e.g. as described in US 5 066 881 where a semi-conducting pyrolized glassfiber layer is in contact with both the parallel rods forming the conductor and the insulation in the stator slot is surrounded by an outer layer of semiconducting pyrolized glassfiber. The pyrolized glassfiber material is described as suitable since it retains its resistivity even after impregnating treatment.

OBJECT OF THE INVENTION:

The object of the invention is to provide a new type of winding for a power transformer or for a reactor, comprising a high-voltage cable.

Contrary to conventional power transformers with windings having insulation, the present power transformer is provided with windings in the form of high-voltage cable having an outer semi-conducting layer which is

earthed in order to substantially eliminate electric potential outside the cable, and in order to reduce capacitive currents.

Earthing of this layer is solved according to the present invention, by providing the high-voltage cable with an outer semi-conducting layer. The winding is provided with spacers arranged to achieve axial pre-stressing in the winding and thus intended to solve the problem of short-circuiting forces in the winding, thereby eliminating the need for force-absorbing clamps in transformers, for instance.

The object of the spacers according to the present invention is also, at a large number of earthing points, to achieve efficient earthing of the outer semi-conductor of the winding for all turns of the winding. Capacitive currents exist in the winding of a transformer, just as in each cable. These capacitive currents flow through the outer semi-conducting layer and cause voltage distribution along the semi-conductor. In order to reduce the voltage to a safe level at the outer semi-conductor, the distance between two earthing points must be relatively short. For frequencies applicable in power distribution (50/60 Hz) the earthing distance (distance between two earthing points) may be up to several meters. One task for the spacers is thus to effect electrical contact between the outer semi-conductor and the earthed spacer.

A shorter earthing distance is required for impulse voltages, transients, because of the higher frequency content in the voltage pulse. The spacers required for impulse earthing do not need to have particularly good contact. Even a small air gap between the outer semi-conductor and the metal part of the spacer can be accepted. If an impulse voltage appears, the voltage at the outer semi-conductor (caused by capacitive currents) will be sufficiently high to produce a spark between the air gap between the outer semi-conductor and the metal part of the spacer. The spark will then produce earth contact between the outer semi-conductor and the metal part of the spacer.

The task of the metal part of th spacer (of stainless steel, for instance) is to collect all earthing currents from the outer semi-conductor. Good earthing of the winding is thus obtained by earthing the spacers.

The windings are thus constructed as a mechanically compact and uniformly earthed winding package which is able to absorb loads such as short-circuiting forces, without transferring the forces to the iron core in a transformer solution.

The invention also aims to provide axial cylindrical ducts between each turn in the winding, where the coolant is correctly distributed so as to satisfy the various cooling requirements in the winding. The cylindrical ducts can be created by spacers inserted when the coil is being wound. The cooling flow is achieved by fans and the spacers are dimensioned to produce flows in the ducts which satisfy the cooling requirement of the individual windings.

Another advantage with the present transformer construction is that the windings can be pre-assembled on cable drums at the cable factory and then be assembled around the iron core on site. This constitutes a major improvement in production technology for these types of transformers.

SUMMARY OF THE INVENTION:

The present invention relates to a winding for a power transformer or for a reactor. The winding comprises a high-voltage cable which can be wound around a core of magnetic material. The winding is provided with a number of axially running spacers separating each cable turn of the winding in radial direction in order to create axial cylindrical cooling ducts.

Thus according to one embodiment of the invention the winding is arranged with axial cylindrical cooling ducts between each turn of the winding lying one on top of the other, said ducts being created by spacers inserted during winding of the coil. The embodiment also includes fans for transporting air through the axial cylindrical ducts. The spacers are dim nsioned in order, at the same pressure drop, to distribute the flow of

coolant so that it satisfies the cooling requirement of the individual axial ducts since the cooling requirement is different for the windings.

The spacer according to the invention is also arranged to axially clamp the winding together to form a uniform winding package that can absorb mechanical short-circuiting forces and also constitute an earthing connection to the outermost layer of the cables. The cables according to the invention are provided with a semi-conducting layer on the surface which must be earthed in order to obtain a zero potential on the surfaces of the winding. The spacer is also arranged with a resilient layer to take up vibrations that may arise in the winding.

Advantageous embodiments according to the present invention are designed with permanent spacers which remain in the winding even after it has been wound, and with temporary spacers which are used during the winding procedure and then removed when winding has been completed.

The temporary spacers separating the turns of the winding in radial direction fulfil the following functions:

1) During winding of the cable which is to form a part of the winding the spacers, both temporary and permanent, shall ensure that the turns of the winding are correctly spaced in radial direction along the entire circumference, even if relatively large forces/torque must be exerted in the winding phase due to the rigidity of the cable. If the spacers are too far apart the winding turns would resemble polygons rather than circles. When individual spacers with small supporting surfaces are used, as many spacers as possible are required, or else spacers with large supporting surfaces.

2) During operation the permanent spacers have the task of maintaining the space between the winding turns to allow passage for a coolant and enable it to cool as efficiently as possible. For this task the permanent spacers should be spaced relatively far apart so that they do not themselves take up too much cross-sectional area and thus deteriorate the flow of the coolant. Only a small number of spacers are required for the mechanical stability of the winding, e.g. with regard to short-circuiting forces.

According to an advantageous embodiment of the invention this problem is solved by some of the spacers, e.g. alternate spacers, being of a temporary nature and removable after manufacture of the winding. This can be achieved in several ways: By providing these spacers with an elliptical cross-sectional area, the long axis of the ellipse being in radial direction during manufacture and then being turned 90° and which can be pulled out or, by being inflatable with a fluid such as air or water which is withdrawn after assembly or by providing them with retractable barbs, etc.

In the embodiments with temporary spacers having a small supporting surfaces against the cable, sufficient of these should instead be placed between the permanent spacers to prevent the turns of the winding resembling polygons rather than circles. In the embodiments provided with temporary spacers with large supporting surfaces it is sufficient with fewer, possibly only one or two.

In the device according to the invention the windings are preferably of a type corresponding to cables with solid extruded insulation used nowadays for power distribution, e.g. XLPE cables or cables with EPR insulation. Such a cable comprises an inner conductor composed of one or more strand parts, an inner semiconducting layer surrounding the conductor, a solid insulating layer surrounding the inner semiconducting layer, and an outer semiconducting layer surrounding the insulating layer. Such cables are flexible, which is an essential property in this context since the technology for the device according to the invention is based primarily on a winding system in which the winding is performed with conductors which are bent during assembly. A XLPE cable normally has a flexibility corresponding to a radius of curvature of approximately 20 cm for a cable 30 mm in diameter and a radius of curvature of approximately 65 cm for a cable 80 mm in diameter. In this application the term “flexible” thus refers to a winding flexible down to a radius of curvature in the order of four times the cable diameter, preferably 8-12 times the cable diameter.

The winding should be constructed so that it can retain its properties even when it is bent and when it is subjected to thermal stress during operation. It is extremely important in this context that the layers retain their adhesion to each other. The material properties of the layers, particularly their elasticity and their relative coefficients of thermal expansion are decisive here. In a XLPE cable, for instance, the insulating layer is of cross-linked low-density polyethylene and the semiconducting layer is of polyethylene with soot and metal particles mixed in. Fluctuations in volume as a result of temperature fluctuations are absorbed entirely as changes in radius in the cable and, thanks to the comparatively slight difference in the coefficients of thermal expansion in relation to the elasticity of these materials, the radial expansion will be able to occur without the layers loosening from each other.

The material combinations stated above should be considered only as examples. Other combinations fulfilling the conditions specified and also the condition of being semiconducting, i.e. having resistivity within the range of 10^{-1}-10^{6} ohm-cm, e.g. 1-500 ohm-cm, or 10-200 ohm-cm, naturally also fall within the scope of the invention.

The insulating layer may consist, for example, of a solid thermoplastic material such as low-density polyethylene (LDPE), high-density polyethylene (HDPE), polypropylene (PP), polybutylene (PB), polymethyl pentane (PMP), cross-linked materials such as cross-linked polyethylene (XLPE), or rubber such as ethylene propylene rubber (EPR) or silicon rubber.

The inner and outer semiconducting layers may be of the same basic material but with particles of conducting material such as soot or metal powder mixed in.

The mechanical properties of these materials, particularly their coefficients of thermal expansion, are affected relatively little by whether soot or metal powder is mixed in or not - at least in the proportions required to achieve the conductivity necessary according to the invention. The insulating layer

and the semiconducting layers thus have substantially the sam coefficients of thermal expansion.

Ethylene-vinyl-acetate copolymers/nitrile rubber, butylymp polyethylene, ethylene-butyl-acrylate-copolymers and ethylene-ethyl-acrylate copolymers may also constitute suitable polymers for the semiconducting layers.

Even when different types of material are used as base in the various layers, it is desirable for their coefficients of thermal expansion to be substantially the same. This is the case with the combination of the materials listed above.

The materials listed above have relatively good elasticity, with an E-modulus of E<500 MPa, preferably <200 MPa. The elasticity is sufficient for any minor differences between the coefficients of thermal expansion for the materials in the layers to be absorbed in the radial direction of the elasticity so that no cracks or other damage appear and so that the layers are not released from each other. The material in the layers is elastic, and the adhesion between the layers is at least of the same magnitude as the weakest of the materials.

The conductivity of the two semiconducting layers is sufficient to substantially equalize the potential along each layer. The conductivity of the outer semiconducting layer is sufficiently large to contain the electrical field in the cable, but sufficiently small not to give rise to significant losses due to currents induced in the longitudinal direction of the layer.

Thus, each of the two semiconducting layers essentially constitutes one equipotential surface, and these layers will substantially enclose the electrical field between them.

There is, of course, nothing to prevent one or more additional semiconducting layers being arranged in the insulating layer.

BRIEF DESCRIPTION OF THE DRAWINGS:

The inv ntion will now b described in more detail with reference to the accompanying drawings.

Figure 1	shows schematically an axial section through the middle of a transformer coil revealing spacers according to the present invention extending axially through the coil,
Figure 2	shows a section of a winding coil provided with spacers according to the invention, along the line A-A in Figure 1.
Figure 3	shows another detailed section corresponding to the section in Figure 1.
Figure 4	shows a section through a spacer at its point of contact with the cable according to the invention.
Figure 5	shows an upper end of one embodiment of the spacer.
Figure 6	shows a lower end of one embodiment of the spacer.
Figure 7	shows a first embodiment of a temporary spacer according to the invention.
Figure 8	shows the spacer in Figure 7 when compressed.
Figure 9	shows the spacer in Figure 7 when expanded.
Figure 10	shows a second embodiment of a temporary spacer according to the invention.
Figure 11	shows the spacer in Figure 10 seen from the end.
Figure 12	shows a third embodiment of temporary spacers according to the invention.

DESCRIPTION OF THE INVENTION:

Figure 1 shows a cross section through a power transformer 1 provided with a winding coil 2 with windings 3 arranged helically, starting at a lower bottom plate 4, and wound upwardly. The windings may be connected to each other but do not have to be. Different windings with different cable diameters are included in the embodiment shown in the Figure. Since the diameter of the cables differs in different turns of the cable as is also clear from the Figure, each winding is provided with axial spacers a, b, c to fit into the axial position in the coil for each winding. A number of spacers 8, 9 are inserted between each winding turn 5, 6, 7. A first spacer 8 is thus

inserted between a first winding turn 5 and a s cond winding turn 6. A second spacer 9 is inserted between the second winding turn 6 and a third winding turn 7, and so on. Each spacer 8, 9 is fixed in the lower bottom plate and is clamped with a clamping device 10 against an upper electrically conducting support plate 11. As can be seen from Figure 1, the first spacer 8 is thicker than the second, for instance, so that a wider duct is formed between the turns of the winding. The winding coil constitutes a part in the transformer which is independent from its iron core and need not be supported by the iron core to compensate for all the mechanical short-circuiting forces occurring. The winding structure may be in contact with the iron core in the "window", but it does not have to be. The winding coil 2 surrounds the leg 12 of the iron core which is connected at its lower and upper ends to a yoke 13 for contact with another leg (not shown).

The spacers 8, 9 have either cylindrical or rectangular cross-section and are provided at least at one end with a clamping device 10 in the form of a threaded nut or a wedge arrangement. As can be seen in Figure 2, the spacers 8, 9 are placed radially outwards from the leg 12 of the iron core with the support plates 11 arranged like spokes. The number of support plates 11 distributed round the winding coil 2 is twelve in a preferred embodiment, but may vary from eight to sixteen, depending on the size of the winding. Five spacers are placed radially through each "spoke" in a winding coil of the present type. The spacers 8, 9 also form axial cylindrical cooling ducts 13, 14 between each radially disposed winding 5, 6, 7. The winding turns are air-cooled, air being pressed through the ducts by fans (not shown). The spacers 8, 9 are placed all around the winding coil 2 and run in axial direction. The spacers are inserted between the turns during winding of the coil.

Each winding coil is thus surrounded by a cooling duct inside which cooling air is arranged to flow. The cooling requirement is different for the windings, which means that the flow of coolant is different in the concentric ducts. In order to achieve correct cooling of the ducts, as indicated above, the ducts are arranged with different dimensions in radial direction. The

pressure drop is the same over all the ducts in order to obtain the desired distribution of the cooling. This means that ducts with little cooling requirement are radially narrower than ducts with a larger cooling requirement. In the cable-wound transformer described in this embodiment, larger spacers are placed between the low-voltage windings, the windings nearest the core, than between the high-voltage windings.

Figure 3 shows an axial cross section through a part of a power transformer with a leg 12, a yoke 15 having one cooling duct, and a winding coil 2. The first spacer 8 is made of metal or reinforced plastic coated with a layer of rubber 16 acting as a spring in order to suppress vibrations in the winding during operation. The spacer in the embodiment shown is also provided on its outside with an open, electrically conducting member 17 in the form of a metal strip or sheath to establish electric contact with the casing and the winding 3. The conductor member 17 is also in electrical contact with the upper electrically conducting support plate 11 via an earth conductor 18. Electric current is then conducted from the support plate 11 out of the transformer and to earth. The support plate 11 may also be made of a non-conducting material, in which case earthing of the conductor member 17 is achieved with a separate conductor. The conductor member in this embodiment is also provided with an air gap, not shown, to conduct transient currents to earth. The end of the spacer 8 extends through a drawing hole 19 in the support plate 11, the clamping device 10 being in the form of a wedge 20. The winding package may be pre-stressed so that the winding acts mechanically as a separate unit. The pre-stressing should not be greater than a level at which the winding is kept in place. The pre-stressing cannot be greater than the XLPE insulation of the cable will stand. In the transformer embodiment, furthermore, the winding package is anchored to the iron core in some suitable manner.

Figure 3 also shows a section through a high-voltage cable 11 for use in a winding according to the present invention. The high-voltage cable 111 comprises a number of strands 112 of copper (Cu), for instance, having circular cross section. These strands 112 are arranged in the middle of

the high-voltage cable 111. Around the strands 112 is a first s mi-conducting layer 113. Around the first s mi-conducting layer 113 is an insulating layer 114, e.g. XLPE insulation. Around the insulating layer 114 is a second semi-conducting layer 115. Thus the concept "high-voltage cable" in the present application does not include the outer sheath that normally surrounds such cables for power distribution. The high-voltage cable has a diameter in the range of 20-250 mm and a conducting area in the range of 40-3000 mm^2.

Earthing of the semi-conducting layer 115 is obtained at operating voltage through contact between the second semi-conducting layer 11 and the metal sheath 17 of the spacer 8. To increase contact between the cable and the earth conductor the cable may be coated with an electrically conducting paint in the area of the spacer.

An advantageous embodiment of a spacer 9 is shown in Figure 4. In this embodiment the spacer 9 consists of an electrically conducting core 25 of stainless steel, for instance, which is coated with a resilient layer 26, preferably of rubber, on both sides of the core, or with a resilient layer surrounding the core. The layer 26 is provided with an air gap 27 somewhere along the surface of the core in order to enable earthing of transients in the high-voltage cable 111 caused by lightning discharges, for instance. The spacer 9 in this air gap is also provided with at least one earth conductor 28 which in one embodiment is in the form of a metal strip or a metal foil with one end cast or glued to the surface of the core 25 and the other end glued to the outer surface of the resilient layer. The earth conductor 28 extends through the air gap 27 and forms an extended spring loop part 29 in the air gap 27, thus providing an improved contact point for the earthing to the second semi-conducting layer 115 of the cable. The earth conductor may also be in the form of an electrically conducting spring cylinder place in the air gap. Other embodiments of the earth conductor which achieve spring contact with the second semi-conducting layer 115 are also feasible.

The earth conductor 28 is intended to take care of earthing th semi-conducting layer at op rating voltage, whereas the purpose of the air gap

is to provide an earthing path for transients. In the spoke arrangement of spacers only one spoke has spacers with earth conductors, so as not to form closed current loops in the winding turn. The spacers of the remaining spokes lack earth conductors but are all provided with air gaps to take care of transients.

The spacer 9, see Figure 5, is connected at its upper end 30 to a draw pin 31 welded on and provided with threading 32 to enable tightening against the upper support plate by means of a nut. Similarly the lower end 33 of the spacer 9, see Figure 6, is connected to a bottom pin 34, also welded on and provided with threading 35 for a nut enabling it to be tightened against a corresponding plate, not shown.

Figure 7 shows a first embodiment of a temporary spacer 50 which has a curvature corresponding to the radius of curvature of the winding at the point where the spacer is to be applied. The spacer 50 is shaped as a curved block and has a large contact surface against a cable. The spacer is also provided with mechanical expanders 52 which, upon manipulation, displace the two radial surfaces 53, 54 away from each other. The displacement is achieved by actuators in the form of separate torsion means or, as shown in the drawing, interconnected torsion means 55. When the surfaces are moved towards each other their long sides overlap and when the surfaces are displaced away from each other the overlap slides apart.

Figure 8 shows the mechanical expander 52 from the end of the spacer in its compressed state. The expanders are in the form of elliptical cams which in this position are oriented in tangential direction.

Figure 9 shows corresponding spacers 50 in expanded state, the elliptical cams having been oriented to a radial position. Turning of the expanders 52 is effected by turning each device manually, either individually or by means of a common actuator via a knob or lever, the devices being interconnected as shown in Figure 7.

Figure 10 shows a second embodiment of a temporary spacer 60 which has a curvature corresponding to the radius of curvature of the winding at the point where the spacer is to be applied. It is constructed in similar manner to the spacer shown in Figure 7 but in the form of a gas or liquid container. The container is provided with supply fittings 62 which are also used as drainage means. The spacer 60 is provided with bellows 64 in its long sides which permit expansion.

Figure 11 shows the spacer 60 from its end, with three supply/drainage fittings 62 through which gas or liquid is arranged to flow.

Figure 12 shows schematically a third embodiment of a temporary spacer 70. As is clear from the drawing, the support means 70 have only a small support surface in contact with the cable. They are applied between the permanent spacers 8 to support the winding when it is subsequently wound. To avoid polygon shape of the winding, four temporary spacers are placed tangentially between the permanent spacers. Each temporary spacer 70 can be positioned in already expanded state, expanded when in place, or placed with a radial orientation. The winding is then wound. After that, the temporary spacers are removed by compressing them or turning them to a tangential orientation. The complete spacer is thus in the form of an elliptical cylinder which is turned 90° in order to remove it from the winding.

Although the invention has been described in connection with a power transformer, it is applicable to both distribution transformers and reactors.

CLAIMS

1. Winding (3) formed as a coil with winding turns situated radially one on top of the other, characterized in that the winding (3) consists of high-voltage cable (111) provided with an outer semi-conducting layer (115), and in that the winding (3) is provided with spacers (8, 9) disposed axially between each turn of the winding to separate the winding, said spacers being provided with at least one earthing member (11, 17, 18, 25, 28) connected to the semi-conducting layer (115) of the high-voltage cable (111).

2. Winding as claimed in claim 1, characterized in that the spacer (8, 9) is provided with at least one resilient layer (16, 26).

3. Winding as claimed in claim 2, characterized in that an air gap (27) is formed between the layers or in the resilient layer (16, 26).

4. Winding as claimed in either of claims 2-3, characterized in that the earthing member (28) is provided with an electrically conducting spring element (29) for contact between the earthing member (11, 17, 18, 25, 28) and the outer semi-conductor.

5. Winding as claimed in claim 4, characterized in that the spring element (29) is situated in the air gap (27).

6. Winding as claimed in claim 2 or 3, characterized in that the earthing member (11, 17, 18) comprises a conductor member (17) in connection with the outer surface of the spacer (8, 9).

7. Winding as claimed in claim 6, characterized in that the conductor member (17) consists of a metal layer substantially covering the surface of the spacer (8, 9).

8. Winding as claimed in any of the preceding claims, characterized in that the earthing currents are arranged to be conducted away from the winding via a radially placed electrically conducting support plate (11).

9. Winding as claimed in claim 8, characterized in that the support plate (11) is provided with drawing holes through which the spacer (8, 9) is passed, the spacer (8, 9) being arranged to be axially clamped against the support plate (11).

10. Winding as claimed in any of the preceding claims, characterized in that the support plate (11) extends radially across the entire winding coil, from the innermost turn (5) to the outermost turn of the winding.

11. Winding as claimed in any of the preceding claims, characterized in that in the area of its contact with the spacer (8, 9), the semi-conducting layer (115) of the winding is coated with an electrically conducting paint.

12. Method of manufacturing a winding as claimed in any of claims 1-11, characterized in that the winding is supported by temporarily placed support members (50, 60) applied in tangential direction between permanent spacers (8, 9) in order to support the winding when it is subsequently wound, after which the temporary support members are removed.

13. Method as claimed in claim 12, characterized in that support members (70) with little surface supporting against the cable are applied between the permanent spacers (8, 9).

14. Method as claimed in claim 12, characterized in that support members (50, 60) with curvature corresponding to that of the winding and with larger surface supporting against the cable are

applied between the permanent spacers (8, 9) in order to support the winding when it is subsequently wound.

15. Method as claimed in any of claims 13-14, characterized in that the support member (50, 60, 70) is made as an expandable and thereafter compressible member.

16. Method as claimed in claim 15, characterized in that the support member (50, 60) is expanded by its radially opposing sides (53, 54) being displaced away from each other.

17. Method as claimed in claim 16, characterized in that the displacement is effected by an expander (52) mechanically pressing the sides (53, 54) apart.

18. Method as claimed in claim 17, characterized in that after expansion and winding the support member (50) is compressed by the expander (52) being caused to resume its original position, whereupon the support member (50) is removed from the winding.

19. Method as claimed in claim 16, characterized in that the support member (60) is expanded by being filled with gas or liquid.

20. Method as claimed in claim 19, characterized in that the support member (60) is compressed by the gas or liquid being removed therefrom, after which the support member (60) is removed from the winding.

21. Power transformer (1) or reactor comprising a winding as claimed in any of claims 1-11.

22. Power transformer (1) or reactor as claimed in claim 21, the winding of which has been manufactured by the method as claimed in any of claims 12-19.

23. Power transformer as claimed in any of claims 21-22, characterized in that the winding is flexible and comprises an electrically conducting core surrounded by an inner semiconducting layer (113), an insulating layer (114) of solid material surrounding the inner semiconducting layer, and an outer semiconducting layer (115) surrounding the insulating layer, which layers adhere to each other.

24. Power transformer as claimed in claim 23, characterized in that said layers (113, 114, 115) are of materials having such elasticity and such relation between their coefficients of thermal expansion that the fluctuations in volume in the layers (113, 114, 115) caused by temperature fluctuations during operation can be absorbed by the elasticity of the materials so that the layers (113, 114, 115) retain their adhesion to each other at the temperature fluctuations occurring during operation.

25. Power transformer as claimed in any of claims 23-24, characterized in that the materials in said layers (113, 114, 115) have high elasticity, preferably with an E-modulus of less than 500 MPa, more preferably less than 200 MPa.

26. Power transformer as claimed in any of claims 23-25, characterized in that the coefficients of thermal expansion of the materials in said layers (113, 114, 115) are of substantially the same magnitude.

27. Power transformer as claimed in any of claims 23-26, characterized in that the adhesion between the layers (113, 114, 115) is of at least the same order of magnitude as in the weakest of the materials.

28. Power transformer as claimed in any of claims 23-27, characterized in that each semiconducting layer (113, 114, 115) essentially constitutes an equipotential surface.

Fig.1

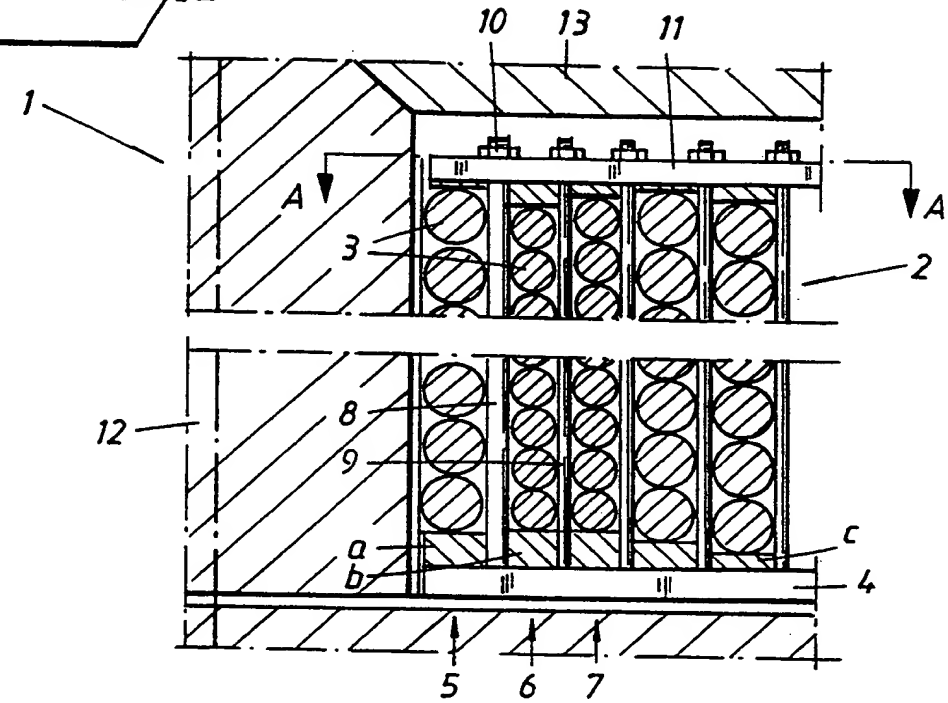


Fig.2

A–A

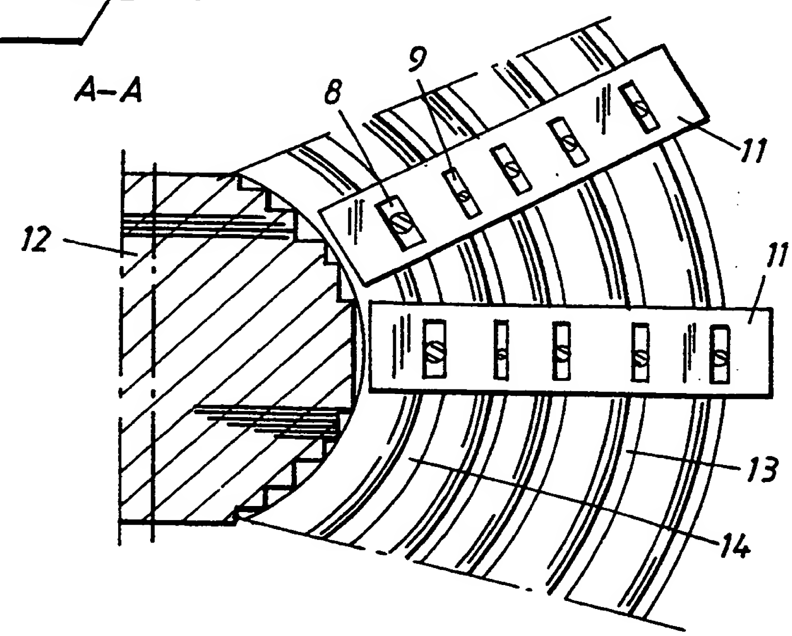


Fig.3

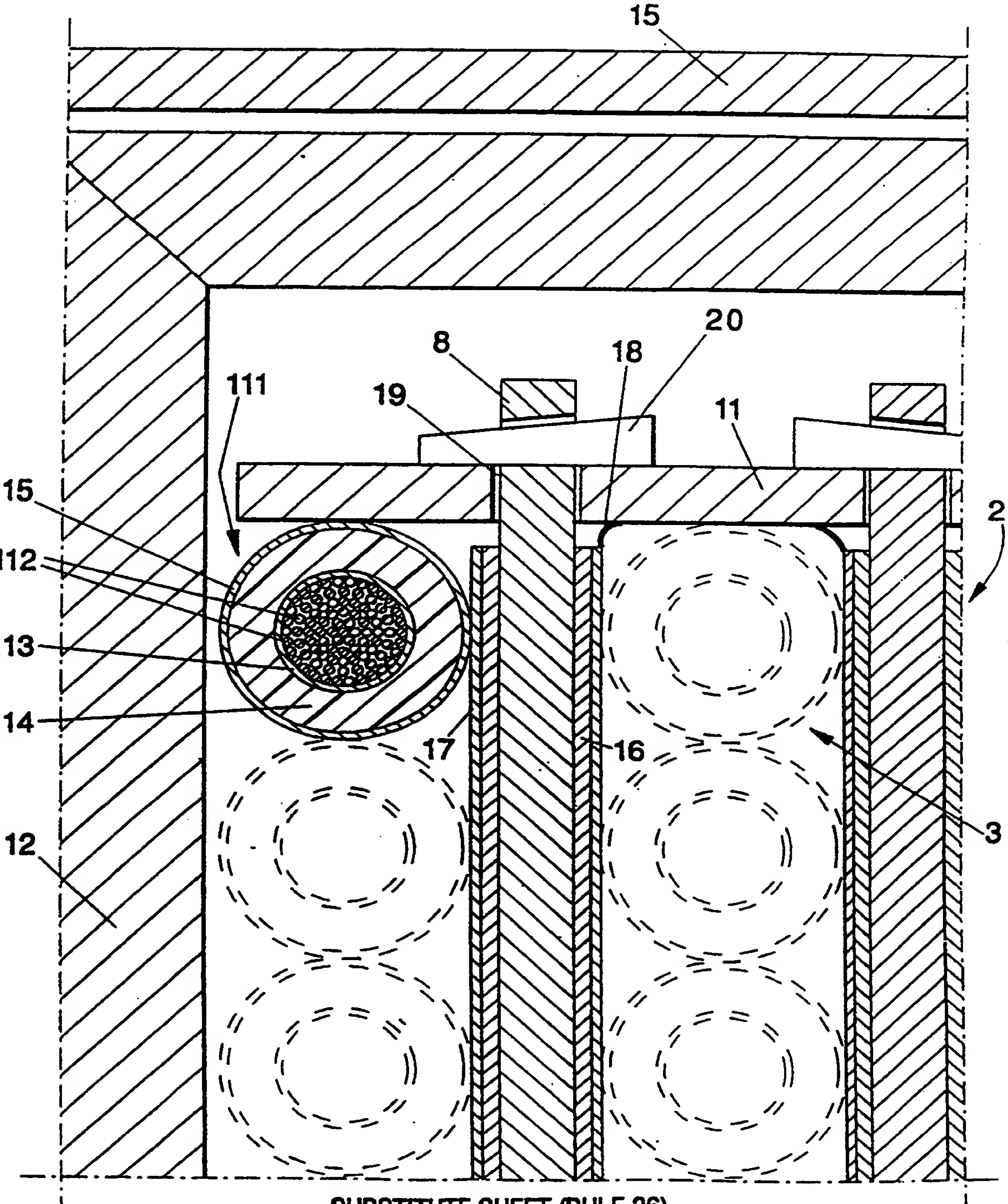


Fig. 4

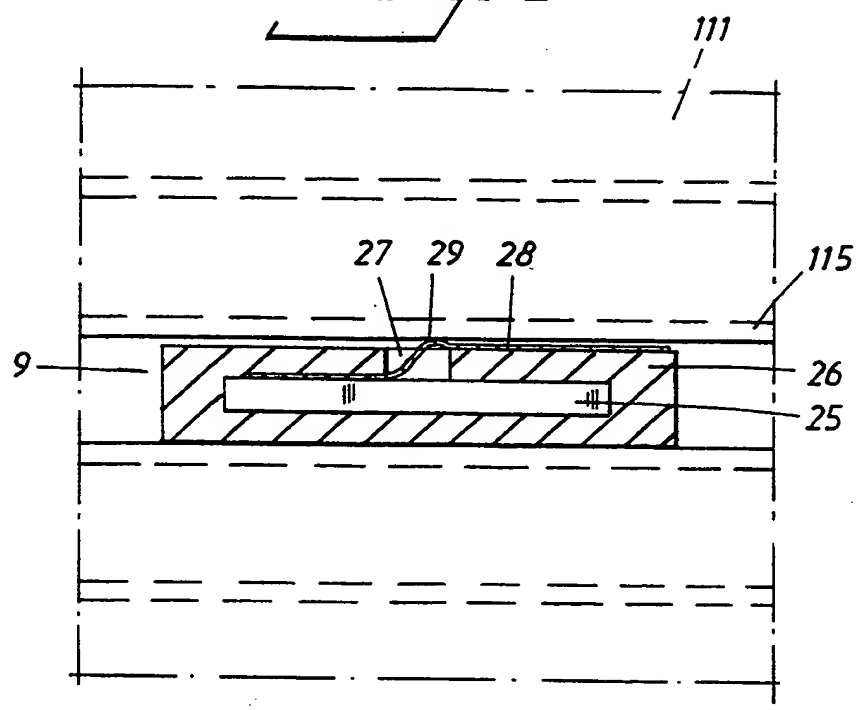


Fig. 5

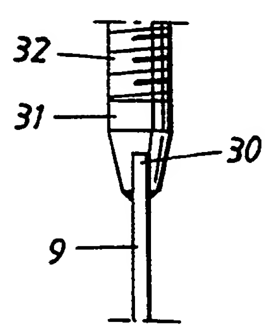


Fig. 6

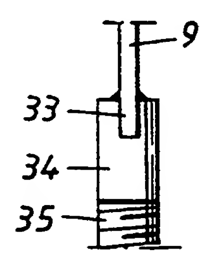


Fig. 7

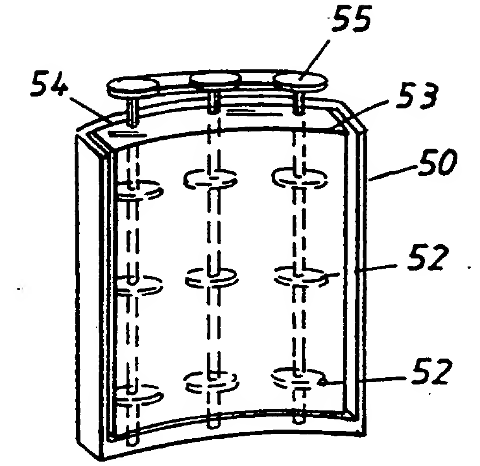


Fig. 8

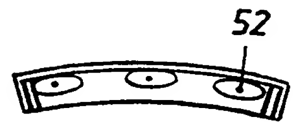


Fig. 9

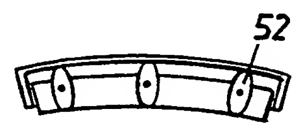


Fig. 10

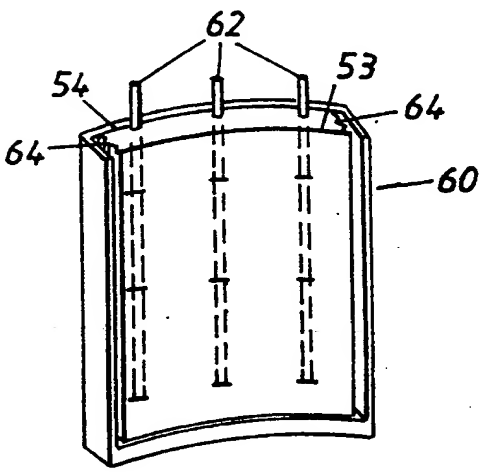


Fig. 11

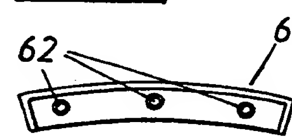
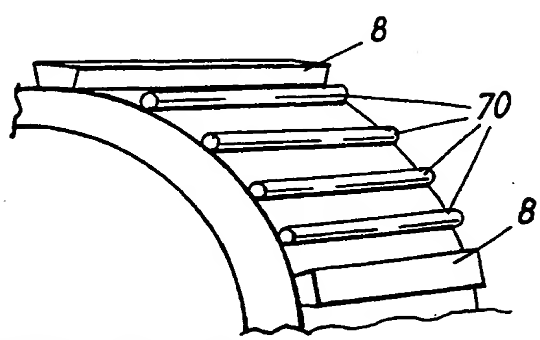


Fig. 12



INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00178

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: H01F 27/34

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: H01F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EDOC, WPIL, JAPIO

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GB 123906 A (BRUSH ELECTRICAL ENGINEERING COMPANY LIMITED), 13 March 1919 (13.03.19), see whole document --	1
A	US 5036165 A (RICHARD K. ELTON ET AL), 30 July 1991 (30.07.91), abstract -- --------	1

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 June 1998	18 -06- 1998
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Magnus Westöö Telephone N . +46 8 782 25 00

INTERNATIONAL SEARCH REPORT
Informati n n patent family members

09/06/98

International application No.
PCT/SE 98/00178

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB 123906 A	13/03/19	NONE	
US 5036165 A	30/07/91	US 5066881 A	19/11/91
		US 5067046 A	19/11/91
		CA 1245270 A	22/11/88
		US 4853565 A	01/08/89

Form PCT/ISA/210 (patent family annex) (July 1992)